APPENDIX B
COST OF GENERATION SUMMARY

As part of the Integrated Energy Policy Report, the California Energy Commission staff developed cost estimates for central-station electricity generation technologies. The *Comparative Cost of California Central Station Electricity Generation Technologies Report* was published on June 5, 2003 and can be found on the Energy Commission's website at http://www.energy.ca.gov/reports/2003-06-06_100-03-001F.PDF. The report is intended to provide a basic understanding some of the fundamental attributes that are generally considered when evaluating the cost of building and operating different electricity generation technology resources.

TECHNOLOGY COSTS

The report does not attempt to capture such site-specific factors such as radial transmission additions, fuel delivery, system upgrades or environmental mitigation expenses. In addition, the levelized cost analysis does not capture all of the system or other relevant attributes that would typically be examined by a portfolio manager when conducting a comprehensive "comparative value analysis" of a variety of competing resource options. A portfolio analysis will vary depending on the particular criteria and measurement goals of each study. For example, some forms of firm capacity are typically needed in conjunction with wind generation to support system reliability requirements. Costs associated with electric power facilities fall into three main categories: investment cost, annual operations and maintenance cost, and variable operating costs.

Initial investment costs are those which are spent in planning, permitting, constructing, and starting up a plant. They are typically financed through a combination of loans ("debt financing") and investment ownership ("equity financing"). The costs are then repaid to lenders and investors over the life of the project. Debt financing usually has fairly rigid conditions related to the term of the loan, the required periodic payments and the security of repayment, much like a home mortgage. Equity financing is usually repaid from the residual revenues remaining after paying all other costs and, as a result, has a higher risk of not being fully repaid compared to debt financing. This analysis makes the assumption that these investments are recovered on a relatively constant annual basis without regard to the amount of generation output. This annual expenditure is then divided over the annual generation to derive the average cost per kWh for the investment or "capital" component

Annual operations and maintenance (O&M) costs are relatively invariant with the amount of output, but would cease if plant operations ended. Operational costs include labor and management, insurance and other services, and certain types of consumables. Maintenance costs include scheduled overhauls and periodic upkeep. Unscheduled or "forced" outages that are a function of usage fall into the final category of costs described below. As with capital costs, these costs are summed and divided over the annual generation output to arrive at the

average cost per kWh. However, unlike capital costs that are relatively insensitive to operational mode, the mode of operation can greatly affect these types of costs. For example, intervals between overhauls may be extended if a plant shifts from intermediate to peaking operations. Less labor may be required for a plant that operates only during the seasonal peak period rather than in baseload. In addition, these costs typically escalate over time, compared to capital costs that are considered constant and fixed once the initial investment is made. Nevertheless, once the mode of operation is determined, the annual O&M costs will vary little and are highly predictable over time.

Variable costs are derived from fuel consumption, maintenance expenditures for forced outages, and other input costs driven directly by hourly plant operations. For a natural gas-fired plant, the largest component of these costs is the consumption of natural gas. Fuel costs can represent two-thirds or more of total average costs. Renewable technologies typically exhibit low or zero variable costs, with the notable exception of biomass plants.

Table 1 shows the results of the cost analyses for various technologies. Expected levelized costs, constant annual payments made over the life of the plants, are shown to provide a common basis of measurement. By construction, levelized costs are given as constant, or real, dollars. This report uses a base year of 2002.

As is evident from **Table 1**, different technologies operate in different generation modes. These modes range from baseload, to intermediate, to a peaking type of facility. A baseload facility generally delivers power at a constant rate whenever the plant is available. A facility may also be used to provide spinning reserve to deliver power during intermittent emergencies on extremely short notice. In between these modes of operation are intermediate/load-following facilities, where a plant can be rapidly ramped up or down to follow daily load cycles. A peaking facility is called upon only during the highest daily loads during the seasonal peaks. Some facilities may provide ancillary services, where a plant provides system support, such as voltage regulation. An intermittent/variable facility may deliver power whenever the driving resource, such as wind, is available.

Comparing technologies on levelized cost alone is not appropriate, considering that different technologies provide different services. For example, wind is very competitive on the basis of cost per kWh, but it can only provide variable output. Other renewable resources, such as geothermal and fuel cells have much more predictable output that may be more valuable, although improvements have been made in wind resource predictability as reflected in recent changes in ISO tariffs.

Risk-management strategies generally use some type of financial or contractual methods to reduce the variability of future costs. Without any risk management efforts, all parties are subjected to cost variations inherent in the marketplace. Risk management strategies used in energy markets include participating in forward markets, vertical and horizontal integration through market segments, long-term contracting, commodities hedging on the natural gas and electricity markets and, of course, diversification of fuel supplies, suppliers and technologies. In this sense, adoption of a renewable energy project may be viewed as part of a greater fuel

diversification strategy, and the State may deem higher cost renewable projects to be an acceptable investment to pay for natural-gas price risk mitigation.

Table B-1
Technology Costs

Technology	Energy Source Fuel	Operating Mode	Economic Lifetime (years)	Gross Capacity (MW)	Direct Cost Levelized (cents/kWh)
Combined Cycle	Natural Gas	Baseload	20	500	5.18
Simple Cycle	Natural Gas	Peaking	20	100	15.71
Wind	Wind; Resource Limited	Intermittent	30	100	4.93
Hydropower	Water; Resource Limited	Load-Following, Peaking	30	100	6.04
Solar Thermal					
Parabolic Trough	Sun; Resource Limited	Load-Following	30	110	21.53
Parabolic Trough-TES	Sun; Resource Limited	Load-Following	30	110	17.36
Parabolic Trough-Gas	Sun/Natural Gas; Partially resource limited	Load-Following; Peaking	30	110	13.52
Geothermal					
Flash	Water	Baseload	30	50	4.52
Binary	Water	Baseload	30	35	7.37

EMERGING TECHNOLOGY COSTS

In addition to the technologies mentioned previously in this report, staff also obtained levelized cost estimates for emerging technologies. Such technologies require further breakthroughs in research and development before they will be considered commercially viable on a central-station scale. These technologies include various fuel cell units, solar photovoltaics (PV), and solar thermal – stirling dish. Of these technologies, Solar PV has shown its usefulness as a distributed generation technology. However, the levelized cost of 42.72¢ per kWh for a 50 MW is uncompetitive at a central-station scale.

The appendices of the staff report contain the cost details that were used to derive levelized cost estimates.

Table B-2
Levelized Costs for Emerging Technologies

Technology	Energy Source Fuel	Operating Mode	Economic Lifetime (years)	Gross Capacity (MW)	Direct Cost Levelized (cents/kWh)
Solar Thermal-Stirling Dish	Sun; Resource Limited	Load-Following	30	31.5	15.37
Photovoltaic	Sun; Resource Limited	Load-Following	30	50	42.72
Phosphoric Acid	Natural Gas	Baseload	20	25	21.27
Molten Carbonate	Natural Gas	Baseload	20	25	10.15
Solid Oxide	Natural Gas	Baseload	20	25	13.04
Hybrid	Natural Gas	Baseload	20	25	9.41